Unlocking Systemic Barriers to Health Innovations for COVID-19 in Africa

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UJ-TRCTI Working Paper Series
P 2021-04
December 2021

Thematic track: Transformative Innovation in Times of Change: Lessons for Africa from COVID-19

DSI/NRF/Newton Fund Trilateral Chair in Transformative Innovation, the Fourth Industrial Revolution, and Sustainable Development (UJ-TRCTI)

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Funding acknowledgement

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Suggested citation: Manyuchi, A.E. and Ouma-Mugabe, J. (2021). *Unlocking Systemic Barriers to Health Innovations for COVID-19 in Africa*. UJ-TRCTI Working Paper Series (WP 2021-04). University of Johannesburg: South Africa.

ISBN: 978-1-998972-41-8

Unlocking Systemic Barriers to Health Innovations for COVID-19 in Africa

Albert Edgar Manyuchi* and John Ouma-Mugabe**

Abstract

COVID-19 has spiked an 'innovation hype' among policymakers, politicians, academics, and the general public around the world. This paper focuses on systemic barriers to health innovations for COVID-19. It shows that the barriers to innovation for COVID-19 responses in Africa are systemic and structural. They are systemic in the sense that they are interrelated and interact in various ways affecting different aspects of national health systems and are structural because they are embedded in the social and physical structures of the national health systems. We argue that many of the emerging COVID-19 health inventions and technologies will remain stunted and will not evolve into innovations if various interrelated interacting social, economic, policy, institutional, and technical barriers in the innovation system are not unlocked. This requires careful choice and deployment of various integrated policy instruments, particularly those spurring further development, deployment, diffusion, and adaptation of nascent health technologies.

Keywords: barriers to innovations; COVID-19; Africa; systems of innovation; mapping health innovations; systematic barriers

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1. Introduction

COVID-19 unmasked Africa's ingenuity and innovative potential. Since the outbreak of the pandemic in early 2020, a wide range of innovations – technological, social, organisational, and policy – have emerged across the continent in both public and private sectors. The pandemic has also stimulated scientific research in fields such as genomics and a surge of focus on epidemiological studies. Organisations such as the World Health Organization (WHO, 2020) and the European Investment Bank (EIB, 2020) have documented or profiled various promising inventions and technologies to address the health dimensions of the COVID-19 pandemic. These inventions and technologies have often been tagged 'African COVID-19 innovations'. However, as we explain in this paper, many, if not most, of the profiled 'African COVID-19 innovations' are still inventions with potential applications and technologies with the potential of 'entry' or deployment into national innovation systems in general and health systems in particular, but strictly do not qualify to be considered as innovations yet because they are not diffusing or spreading with social and economic impact or value. Thus, the word innovation in the context of COVID-19 has been loosely used by media, non-academic actors, as well as some think tanks and academics. This misleads public policy for COVID-19 and ignores problems in the innovation process.

This study provides a succinct analysis of different interacting technical, economic, social, policy, regulatory, and institutional barriers to the dissemination of COVID-19 innovations. It attempts to answer two related questions: What are the main systemic barriers to the development, diffusion, and deployment of innovations to tackle health challenges or aspects of COVID-19 in Africa? And, what policy instruments and policy mixes would unlock the barriers and spur the innovations to help banish COVID-19 in Africa? This paper is about policy for unlocking the systemic barriers to the diffusion and deployment of technologies and inventions to help address the health effects of the COVID-19 pandemic. The study places emphasis on policies because the content of policies generally influences the dissemination of innovations. In this paper, policy instruments refer to measures or actions that governments purposefully put in place to influence innovation processes and activities aimed at addressing health challenges associated with the COVID-19.

The paper is organised as follows: Section two provides an overview of health and socio-economic challenges that the pandemic is causing and then discusses the challenge of innovation in African national health systems. It argues that African countries have tended to make a dichotomy between health and economy, where health is treated as a social sector, and the provision of health care is often considered as a social service that burdens the economy. This approach seems aligned to Science, Technology and Innovation (STI) and industrial policy rationales founded on economistic framings such as 'economic competitiveness' and 'economic growth'. It misleads public policy and helps to keep countries' investments in STI and manufacturing misaligned to health security goals or imperatives. The COVID-19 pandemic is, hopefully, going to change this and policymakers in Africa will get to appreciate that health and human wellbeing are foundations of economic competitiveness and security.

The third section outlines the conceptual approach of this study. Drawing on literature on national systems of innovation (NSI) and health innovation systems, the study frames or conceptualises barriers or impediments to innovations to address health aspects of COVID-19 as systemic, embedded, and interacting in social, economic, and health systems of nations. It is essential to unlock or remove the systemic and embedded barriers and speed up the diffusion and deployment of emerging innovations. We argue that countries need systemic policy measures supported by improved institutional configurations that are well aligned with each other.

Section four briefly presents the methodology and research questions of this study. In this section, the multi-methods of data collection, including in-depth individual interviews and focus group discussions with purposely selected informants and participants, are highlighted. In addition, the validation or quality assurance mechanisms, as well as the limitations, are elaborated.

In section five, we map innovations for tackling health aspects or challenges posed by the COVID-19 pandemic. The mapping is largely based on secondary sources, in particular reports by WHO, the African Union (AU), the European Investment Bank, and the media. While we do not claim that our secondary literature review was exhaustive, it was extensive and had the necessary depth to cover the subject of research. And finally, the findings of the study and the recommendations are provided in sections six and seven, respectively.

2. The COVID-19 pandemic and innovation challenge in Africa

The COVID-19 pandemic is a systemic and transformative crisis that is irreversibly affecting health, social, economic, and political activities around the world (Mugabe, et al., 2020). It is undermining prospects of attaining Africa's aspirations articulated in Agenda 2063[1] and global SDGs. Economic growth in Africa is projected to contract by 7.8% in GDP, particularly in small economies and merchandise exports by 17% (UNCTAD, 2020). On the social front, the pandemic has disrupted social and religious activities with the likelihood of exacerbating mental health and social unrest (Matthewman & Huppatz, 2020). Lockdowns and restrictions on international travel are affecting the mobility of people and goods, affecting regional integration and globalisation processes around the world (McNamara & Newman, 2020). The pandemic is also likely to widen social and economic inequalities, as more than 30 million school-going children are locked out of education during various lockdowns in 2020 because they cannot access digital learning.

Another formidable challenge that COVID-19 poses relates to the weakening of African national health systems and the worsening of the already huge burden of disease on the continent. The pandemic has overstretched the capacity of most African national health systems. Recent studies show that in most African countries, health systems have been relatively weak, as manifested in low budgets for health, poor infrastructure, limited health personnel, and poor governance regimes (Mugabe, et al., 2020). Few countries have hospitals equipped with functional Intensive Care Units (ICUs) and health workers with

[1] See African Union, Agenda 2063: The Africa We Want, https://au.int/en/agenda2063/overview

specialised skills to treat illnesses associated with cancer, diabetes, and other chronic diseases. There are shortages of Personal Protective Equipment (PPE), regents, and testing equipment such as swabs.

Overall, COVID-19 has disrupted social and economic activities and weakened national health systems. The pandemic may be both a cause and consequence of the fragility of health, socio-economic, and ecological systems around the world. However, it offers countries, particularly African ones, unique opportunities to find pathways out of the current health inequalities and the huge burden of disease. Innovation – the introduction and application of 'new' practices, products, processes, and institutions (normative and agency types) – have been key in responding to epidemics and pandemics in the past (Niang, et al., 2021). Hence, innovation (technological, social, and organisational) is critically required for an effective response to the COVID-19 pandemic.

Noteworthy, the COVID-19 pandemic is a transformative crisis; that is, it is a crisis that causes positive and negative as well as direct and indirect changes to people's ways of living. In addition, it is a transformational crisis in the sense that it has stimulated a huge surge in political and public attention to the role of innovation in health. It is reawakening national and international attention to the role of research and innovation (R&I) in health security. Media and research reports have stressed the importance of building scientific research and innovation capabilities of countries to respond to pandemics in general and COVID-19 in particular (Mugabe, 2020). In a 2018 study, Quick (2018) emphasises the urgency of countries building scientific and technological preparedness for future epidemics and pandemics. Overall, building science and innovation capabilities, and perhaps even more important, utilising existing innovation capabilities to respond to the pandemic and future complex crises related epidemics, need to be considered as part and parcel of countries' long-term efforts to build and/or strengthen their National Systems of Innovation (NSI) in general and national health systems in particular. It cannot be achieved through ad hoc short-term isolated policy interventions that are based on framings of innovation and innovation processes as linear involving inputs and outputs of R&D (Stone & Lane, 2012). Indeed, innovation is a complex process characterised by nonlinearity and uncertainty, embedded in socio-political and economic contexts that are themselves dynamic (Kline, 1985). Thus innovation is key to ending COVID-19 while ensuring that the African health systems are strengthened and resilient to future pandemics and disease outbreaks.

In the next section, we outline the conceptual contours guiding this study and then propose a typology of barriers to COVID-19 innovations. The conceptual approach emphasises the systemic nature of both innovation processes and barriers to specific innovations in national health systems.

3. A conceptual outlook

3.1. Systems of innovation approach

The concepts of national systems of innovation (NSI) and national health innovation systems (NHIS) have gained currency in academic research and policy processes in many developed and developing countries (Lundvall, et al., 2009; Mugabe, 2005). The NSI concept is increasingly used to frame STI policy design and governance in a growing number of African countries. Its usage can be traced in national STI policy frameworks of Botswana, Ethiopia, Namibia, Kenya, South Africa, Seychelles, and more countries in Africa (Muchie, et al., 2003). The NSI has been designed as a "network of institutions in the public and private sectors whose activities and interactions initiate, import, modify, and diffuse new technologies" (Freeman, 1987). The network comprises interrelated policies, agencies, and activities that spur the introduction, diffusion, and application of new products, processes, practices, and services to generate new value.

The NSI conceptual framing treats innovation as an interactive non-linear process involving various actors (in public and private sectors and civil society) and policy instruments. Innovation is viewed as an outcome of interconnected or networked systems of private companies (firms) or private individuals, research institutions, users or customers, financing agencies, training institutes, and policy and regulatory agencies operating within a national context (Mytelka & Smith, 2001).

Applying the NSI concept in policymaking has a number of advantages. First, it enables decision-makers to treat innovation as a process that involves social, cultural, and political changes. Actors in innovation processes tend to be from a diverse range of backgrounds and play different roles in activities leading to the development, adoption, and diffusion of technologies. Innovation is not an outcome of a single event or a product from an isolated person or agency. A systemic view of innovation requires policymaking to focus on long-term collective processes and not isolated projects of individual scientists and entrepreneurs.

Second, the NSI approach makes it possible for policymakers to examine the whole 'environment' influencing technological and institutional change instead of narrowly or exclusively focusing on R&D inputs such as national Gross Expenditure on Research and Development (R&D) (GERD) (Grobbelaar, 2006). The overall national context – including macroeconomic and political conditions – is a key determinant of firm-level or public institutional level efforts at innovation. The context influences inter-institutional linkages or relationships, particularly between public and private sector agencies. Policy and policymaking processes play essential roles in establishing conditions within which the actors (firms, public R&D institutes, and universities) make decisions about innovation (Manzini, 2012). Policies generally create the mandate for these institutions. Policies can facilitate synergies between institutions and direct investments into these institutions as well as innovative activities they undertake.

Third, the NSI approach puts emphasis on the role of learning and the building of learning capabilities. Innovation is a learning process, and firms, public institutions, and countries are learners. According to Mytelka (2016), "[l]earning and unlearning on the part of

policymakers, practitioners, users, and producers of all sizes in an emerging or established innovation system are thus at the heart of the system's ability to respond to new challenges such as those resulting from the growing knowledge intensity of production, and the energy and environmental challenges that we are currently facing" (p. 27).

It is important to place emphasis on dynamic national systems of innovation (NSI), that is, everchanging and adaptive systems of innovation are open and characterised by inflow and outflow of information, skills, knowledge, products, and other forms of innovation (Etzkowitz & Leydesdorff, 2000). The openness of the NSI largely influences or determines its learning capabilities (Patrick, et al., 1997). Less open innovation systems tend to be inimical to learning as they restrict the inflow of innovative ideas, new technology, new information, and new skills. They do not adequately enable local firms and public institutes to be exposed to and learn from the external environment. More open NSI foster the inflow of new skills, information, and technologies. Firms and public institutes in such systems interact more with foreign actors, thus acquiring new information and technologies.

The dynamism of an NSI is determined by the density and intensity of interactions of its actors. A more dynamic NSI has dense and intensive actors' interactions involving public and private sectors and between producers and users. The interactions are both formal and informal, often stimulated by deliberate policy measures. Although problematic and limited, common approaches to measuring interactions within the NSI include co-publications, co-patenting, and joint funding and joint implementation of R&D projects among various individuals and institutions (Bartels & Koria, 2014).

Governments play critical roles in the development of NSI. They are responsible for managing the formulation and implementation of policies for R&D, technology development and procurement, and technological innovation in general. Governments have the responsibility of financing R&D and innovation activities and regulating the development and procurement of new technologies. They are key actors in the NSI. Numerous studies show that the effectiveness of government policy interventions and financing influence the growth and dynamism of NSI (e.g. Lundvall, 2004). We note that African governments can play an important role in facilitating dynamic systems of innovations through developing and promulgating effective policies for innovation.

Issues pertaining to barriers to innovation are covered in a wide range of literature on NSI. Earlier work on NIS, such as Freeman (1981), Dosi, et al. (1998), and Lundvall (1992), gave attention to issues of barriers to innovation with an emphasis on factors that impinge on countries' technological innovativeness and economic performance. Different kinds of barriers to innovation activities and the performance of NSI are categorised in the literature. For example, Dosi, et al. (1998) focus on issues of institutional articulation and economic incentives and how different forms of intra- and inter-agency linkages influence innovation and technology diffusion at the firm and national levels.

In a recent study, Borras and Edquist (2019) argue that clearly identifying obstacles and barriers in the innovation system is a necessary first step for defining the scope and the nature of policymaking. They emphasise that the choice of policy instruments is critical in

unlocking barriers in the innovation system. Policy instruments are purposive and used to influence the direction of innovation. Examples of policy instruments for innovation include economic instruments such as tax incentives for R&D, reduced interest rates, and direct grants. Other forms of policy instruments are regulatory, e.g. intellectual property rights and bioethical regulations, and soft instruments that include public-private partnerships.

3.2. National health innovation systems

Drawing on and applying the NSI approach, a number of studies such as Mugabe (2005) and Chataway, et al. (2007) have proposed the notion of national health innovation systems to describe interacting configurations of institutional actors, activities, and policies at various levels of governance to spur innovation for and innovation in health. Chataway, et al. (2007) consider national health innovation systems to be "networks, which link groups from different sectors around a particular health problem… Existing health innovation networks are fluid and operate within and across national, sectoral and micro levels of systems of innovation. Collaboration is at the heart of these networks. While innovation requires a strong knowledge base – good research institutes and universities – that knowledge will not automatically be transferred upstream to the creation of products without strong links with other sectors and a dynamic interplay of users and producers of knowledge at different stages of the innovation cycle" (p. 4).

Health innovation systems subsist in the NSI and are interdependent with other systems such as energy innovation systems, digital innovation systems, transport innovation systems, and many others (Dinesh, et al., 2016). In fact, there is a mosaic of interacting sub-systems of innovation in the NSI. Therefore, the challenge for innovation policy is to address systemic problems in the innovation process and not to fix isolated problems manifested in specific sectors (e.g. energy, Information and Communication Technology (ICT), and health). For this reason, we argue that barriers to innovations for tackling the health dimensions of the COVID-19 pandemic are systemic and pervasive. They occur in or emerge from 'non' health sectors (e.g. energy and transport) but impinge on the realisation of health goals in the fight against the pandemic.

Having dealt with systems of innovations, in the next subsections, we propose a typology of innovations for COVID-19 and a typology of systemic barriers to innovation. These typologies are suggested for illustrative purposes and are not rigid classifications of innovations and barriers to innovations.

3.3. Typologies of innovations for COVID-19

The typologies of innovations for COVID-19 elaborated in this paper are informed variously by existing literature. According to Chandy and Pranhu (2010), innovation typologies can be framed from the innovation concept, the customers targeted by the innovation, the firms implementing the innovation, the innovation features, and innovation effects dimensions. In general, innovation typologies are premised on the national, regional (Navarro & Gibaja, 2012), sector, and industrial (Sandven, 1996) units of analysis. A few attempts at providing an integrated and holistic framework have been made as well (Rowley, et al., 2011). Deriving from these, we developed our typologies of innovations for COVID-19 using a holistic approach, as shown in Table 1 (below).

Table 1: Typologies of innovations for COVID 19.

Nature of Innovation	Radical innovation
	Incremental Innovation
Type of Innovation	Product
	Process
	Organisational/Institutional
Effect of innovation	Economic
	Social
Innovations and knowledge	Science-based and informed
	Interactive learning
	Internationalised-unlimited to national level

Source: Authors' own.

Innovations to tackle or address health aspects of COVID-19 fall in the following categories: technological (e.g. digital apps, ventilators, diagnostic kits, PPEs, and masks), and social and organisational (e.g. social/physical distancing). They can also be incremental (e.g. improvement in or on an existing technology such as a mask) or radical (development and deployment of new vaccines or anti-viral drugs). Incremental innovations are about improving existing technologies and do not require huge leaps in knowledge production. The converse is true of radical innovations that involve radical changes in existing technological systems through new knowledge production and application. Radical innovations, defined as innovations that create revolutionary changes and generate far-reaching economic and social effects, tend to create an entirely new pathway or regime of technology, institutions, and governance.

Social innovations are about changes in social institutions and practices. They generate new routines and/or modifications in existing practices or even a new social agency but do not necessarily have a direct impact on an existing technology or technological system.

Health innovations for COVID-19 can also be scientific in the sense that they involve the production and use of new knowledge to enhance understanding of the coronavirus, e.g. how it mutates in infected persons. They may include innovations in epidemiological studies, improving the conduct in order to reduce the rate at which the disease spreads.

In summary, innovations for COVID-19 comprise a diversity of interacting technological (technical), organisational, and social innovations in a national health system needed to address different aspects of the COVID-19 challenge. The different aspects of managing COVID-19 include (a) preventing the spread of the virus through measures such as wearing of masks, social distancing, and sanitising, (b) testing to detect infections and tracing to establish the spread of the virus, (c) treating infected patients, and d) vaccines.

As stated before, not all the profiled or documented inventions for COVID-19 are really innovations. Most of the so-called innovations are inventions that have not been deployed or proven to work; they were not commercialised and may never be commercialised. Therefore, the term innovation was loosely used in the context of COVID-19 profiling or documentation. Given this, it is important to have a much more grounded and restrictive definition of innovations for COVID-19, which will provide a clear understanding of what constitutes an innovation.

3.4. Typology of barriers to innovation

What constitutes a barrier to innovation? It is an impediment to the development, introduction, diffusion, and implementation of any type of innovation outlined in our typologies of innovations. While in other settings, barriers may be considered as enablers, we have not integrated this dimension to be able to pronounce them as such in this paper. There are at least five groups or categories of barriers to innovations: technical, economic, social, organisational or institutional, and policy/regulatory barriers (Parente & Prescott, 1994; Philibert, 2006; Zelenika & Pearce, 2011).

Technical barriers consist of hindrances to the development, diffusion, and transfer or acquisition of a product or a process due to design complexity and/or inadequacy of scientific and technological knowledge.

Economic barriers include fiscal disincentives, high cost(s) of R&D, high costs of technology procurement, and unfavourable macroeconomic conditions in general (Bartels, et al., 2016).

Social barriers include resistance by individuals and/or communities, or society as a whole, to innovations due to perceived or real social risks. Perceived risks are 'imagined' negative consequences of a particular innovation – its introduction, diffusion, and implementation. Because of the imagined negative consequences, individuals may reject or initially resist the adoption of an innovation (Chalmers, 2013).

Organisational or institutional barriers include entrenched norms, procedures, and routines – established or prevailing ways of doing things – that make it difficult for an agency (within the public and private sector) to develop and adopt as well as implement new technology or innovation. For example, the norms, procedures, and routines may relate to how communication within an agency or between agencies is organised and managed. According to a wide range of literature on organisational behaviour and management, heavy bureaucratic structures with many levels of controls and approvals stifle creativity and innovation among employees. Organisational barriers also include entrenched business models, limited in-house skills, and finances for and knowledge on the development and use of new technologies (Pourkiani, et al., 2013).

Policy and regulatory barriers to innovation include an absence of R&D and innovation policy, incoherence and uncertainty in R&D and innovation policy, weak policy implementation capacity, absence or existence of weak technical standards, and fiscal and tax regulations that hinder investment or raise costs of investment in innovation. While

ambiguous and/or weak intellectual property protection measures have traditionally been viewed as negatively affecting innovation, there is evidence that poor intellectual property regimes may have a neutral or positive effect on innovation. There are political considerations or factors that generate policy or regulatory barriers. Policy and regulations as outcomes of political negotiations and competition face resistance in implementation from certain political groups who may lose support from their constituencies if certain policy and regulatory interventions are instituted. Such groups tend to resist the implementation of certain policy and regulatory measures if they do not serve their political, ideological, and even economic interests (Acemoglu & Robinson, 2000).

Barriers to the development, transfer, and diffusion of an innovation or new technology or even the implementation or deployment of existing technologies tend to be systemic in the sense that they emerge from and are connected to various aspects of the NIS. Wieczorek and Hekkert (2012) focus on the systemic nature of barriers to innovation processes and activities in NSI. They argue for systemic policy instruments to address structural and functional NIS barriers to innovation:

> *"The basic idea behind systemic instruments is that they aim to address problems that arise at the innovation system level and which negatively influence the speed and direction of innovation processes. These problems are often referred to as systemic weaknesses or systemic failures. They hinder the operation and development of the innovation system as a whole and the presence of these system failures is often considered to be a new policy rationale, replacing the neoclassical market failure. Examples include innovation networks that are either too weak or too strong, and poorly articulated demand for innovation or institutional capacity problems." (Wieczorek & Hekkert, 2012, p. 74).*

Mazurkiewicz and Poteralska (2017) also demonstrate that many of the barriers to technology transfer are systemic and require systemic policy interventions. They define barriers to technology transfer as any limitations that hamper the effective functioning of "a technology transfer and research commercialization system, and, as a result, block interactions between the R&D sector and enterprises, therefore impeding the development of innovative entrepreneurship" (p. 457). They provide the following categorisation of barriers: technical, organisational-economic, and system barriers. These kinds of barriers interact systemically or have causal relationships.

Barriers to innovation are systemic and pervasive in the sense that their effects tend to spread across different sectors such as health, energy, water, transport, and manufacturing. This is particularly so with institutional barriers related to poor linkages or disarticulation in the NSI, for example, the absence of a culture of cross-sectoral coordination among departments of health. ICTs and energy may lock digital health innovations out of healthcare in a country. A country with a poorly functioning or weak energy infrastructure is likely to have difficulties managing vaccination against COVID-19 or even deploying digital applications in the diagnosis and epidemiological management of the disease.

Related to institutional barriers are impediments pertaining to policy incoherence. Foxon and Pearson (2008) examine policy processes for building sustainable innovation policy regimes. They put emphasis on measures that promote co-evolution of technology and policy processes, bringing together different policy goals (e.g. environmental sustainability) and innovation goals. Foxon and Pearson (2008) take a systems approach and stress that innovation and technology diffusion are systemic, dynamic, and non-linear processes in which institutional and technological factors interact in uncertain ways.

Bartels, et al. (2016) provide an analysis of barriers to innovation and innovativeness in Ghana using the NSI conceptual approach. They show how limited skills, low technological capabilities in ICTs, weak organisational capacities and institutional linkages, unsophisticated markets, and deficits in fiscal policy interact in systemic ways to impede innovation and the building of innovation capabilities in the country. Weak interactions between government, private sector enterprises, and research institutes and universities are also identified as key barriers to innovation.

Desveaux, et al. (2019) provide a good analysis of organisational and policy level barriers to health innovations. Their study is about the 'plague of pilots' – "where innovations fail to become part of the routine practice because of limited funding or ability to scale to broader sectors of the health care system." They conclude: "Context and culture drive changes in the use of technology, highlighting the central role that policy reform will play in the success (or failure) of the digital health agenda" and "organizational factors, such as the capacity to innovate, readiness for the digital health innovation, availability of funding, and extent of changes required to implement innovation, also influence the adoption process and thereby impact the uptake of digital health innovations in practice" (p. 2).

Given this, a barrier to innovation for COVID-19 can be viewed as any systemic technical, economic, organisational, regulatory or policy, and social impediment to the development, commercialisation, and diffusion of social and product innovations. The barriers should be of temporary nature.

4. Methodological approach

The preceding section is a review of the literature laying out the conceptual outlook of this paper. It provides an appropriate framing for the analysis of barriers to innovations for COVID-19 in Africa. The main research questions addressed in this study are:

1. What are the main systemic barriers to the development, diffusion and deployment of innovations to tackle health challenges or aspects of COVID-19 in Africa?

2. What policy instruments and policy mixes would unlock the barriers and spur the innovations to help banish COVID-19 in Africa?

To answer these research questions, a review of secondary literature focusing on the typologies of innovations for tackling health challenges or aspects of COVID-19 in Africa

was done. The focused review specifically analysed case studies in recent academic papers in journals such as Nature and databases of the African Academy of Sciences (AAS) and Scopus. Although the search was not limited by years, the fact that the paper is dealing with COVID-19 innovations naturally and unintentionally emphasised searches to 2019 to the present. Additional research on company and university websites highlighted in the reviewed literature was carried out.

Following the literature review exercise, mapping of different innovations for COVID-19 was done guided by the typology proposed and drawing from or using empirical information from published reports by organisations such as the WHO, AU, and EIB. The mapping encompassed illustrative cases of ongoing scientific research (R&D) initiatives in African institutions. Some of the cases were illustrative of 'pipeline' or 'potential innovations'. A ranking of different innovations was done using the following criteria: the typology of the innovation, awareness of the existence and spread of the innovation, and stage of development and level of investment in the innovation. This was done by reviewing documentation (including reports and newspaper clippings). Results of the mapping exercise are presented in the next section.

Telephone and WhatsApp interviews were also carried out with purposively selected participants. These were persons considered to be leading the COVID-19 response across many African countries, including Kenya (8 participants), Zimbabwe (6 participants), South Africa (12 participants), Cote d'Ivoire (5 participants). Four focus group discussions (FGDs) were conducted with participants from Botswana (4 participants), Uganda (4 participants), Senegal (4 participants), and Nigeria (4 participants), who discussed specific COVID-19 innovations. Participants in the FGDs also ranked specific innovations based on the following multi-criteria approach: alignment with national and local COVID-19 health emergence goals or priorities, the potential of the innovation to be rapidly commercialised or existence of a potential market for the innovation, scalability of the innovation, and availability of skills and potential for capacity building in developing and using the innovation.

To complement data from FGDs, telephone interviews were conducted with key informants. These were nine purposively selected persons (three from the research community, two from private companies involved in the production of PPEs, and four policymakers from departments of STI and trade in Kenya and South Africa. These interviewees were experts in their areas of work. In addition, using WhatsApp, opinions on and perceptions of barriers to specific innovations such as masks, social distancing, and potential vaccines were gathered from 17 respondents randomly identified among post-graduate students at two universities in South Africa. The views of FGDs participants and post-graduate students were used to validate the findings from other respondents.

The data collection was stopped when saturation was reached, i.e. when the same responses were given by a number of respondents, and no new insights could be gleaned from the responses. Data from these various sources were analysed, and summaries based on the data were written. These summaries were reviewed. The final summaries are presented as the findings in this chapter.

A study of this scope has some limitations. The participants were purposively recruited, and their responses may have been affected by desirability bias. This was minimised by using multi-research methods to collect the data. The number of study participants may be considered few. However, most of the selected participants were experts or knowledgeable in the subject under research. As a limitation, most participants were based in African countries. This may limit the generalisability of the findings beyond the African continent.

5. Mapping health innovations for COVID-19

The initial months during the pandemic witnessed a huge surge of investments in scientific research and innovation processes to develop and deploy products, processes, and practices to tackle the health aspects or challenges of COVID-19. Governments, private companies, individuals, research institutes, and development assistance agencies have been engaged in numerous initiatives to produce scientific knowledge on the virus and the COVID-19 pandemic, manufacture PPEs and other medical equipment such as ventilators, develop vaccines, and a wide range of digital tools to address various aspects of testing, contact tracing, and treatment. Firms, including small and medium enterprises (SMEs), are at the forefront of manufacturing PPEs and sanitisers. Research institutions and universities in many countries have mobilised their faculties to undertake research on various aspects of the virus, including epidemiological studies, and are building data science on COVID-19. Community-based health interventions, including testing, tracing, and treatment, are being scaled up in some countries in Africa.

In August 2020, the African Union Development Agency-NEPAD (AUDA-NEPAD, 2020) produced a 'white paper' on 'Harnessing Innovation and Emerging Technologies to Address the Impact of COVID-19 in Africa'. The paper profiles scientific research and innovation initiatives aimed at addressing the health impacts of the pandemic. Table 2 below provides a summary of the initiatives.

Table 2: Examples of Research and innovation initiatives for COVID-19 health impacts.

Initiative Category	Specific Research and Innovation Focus	Institution/Country
SARS-CoV-2 Genome Sequencing	• Using genomics to develop candidate vaccines	University of Cape Town, South Africa
Manufacturing Health Equipment and use of new technologies	• Production of PPEs using 3D printing • Production of face masks or shields using 3D-printing • Ventilator prototypes • Use of robots in contact tracing and enforcement of social distancing measures	Addis Ababa University, Ethiopia University of Pretoria (MakerSpace Centre), South Africa Harare Institute of Technology, Zimbabwe, Kenyatta University in Kenya Ministry of Health, Rwanda Government of Tunisia

Health Diagnostics	• 1US$ less COVID-19 testing kit • Simple to use testing kit • Swab tube dipstick • Accessible web-based platform X-ray that scans lungs	Pasteur Institute, Senegal Incas Diagnostics and the Kwame Nkrumah University of Science and Technology in Ghana Makerere University in Uganda Tunisian National Institute of Applied Sciences and Technology (INSAT)

Source: AUDA-NEPAD (August 2020).

In July 2020, the European Investment Bank released 'Africa's digital solutions to tackle COVID-19', which documents a variety of digital products, applications, and practices that have been developed to address health, social, and economic challenges posed by the COVID-19 pandemic. To avoid including inventions that do not qualify as innovations, only digital innovations for health that were mentioned in this report are mapped in table 3 below.

Table 3: African digital health innovations to tackle COVID-19.

Type of innovation	**Overview of health usage or utility**	**Innovator/Institution/ country**
Contact tracing applications	• *Msafari*, application for tracing movements of people who have contracted the coronavirus or have been in contact with infected persons on public transport • *Wiqaytna*, mobile phone contact tracking application that cross checks movements of persons who are supposed to be in quarantine • PGuard robot circulates in Tunis and other cities equipped with speakers and cameras to broadcast safety instructions and monitor compliance with social distancing and mask-wearing requirements	Fablab, an innovation hub, in Kenya Government of Morocco Enova Robotics, a private company, in Tunisia

Health system applications	**Zipline drones** used to collect test samples from health facilities in rural areas and deliver them to medical laboratories in urban centres in Rwanda and Ghana **Humanoid robots** used to screen 50-150 people per minute, monitor patients and help minimise physical contact, also deliver medicines and food to patients' rooms, thus helping to protect health workers **mHero,** healthcare software that helps to connect ministries of health centres and health workers in rural areas. It is a two-way mobile phone communication system that was used during Ebola epidemics in Liberia, Guinea, Sierra Leone, and Uganda **Wellvis** app is an application allowing users to self-assess their coronavirus risk category based on their symptoms and exposure history. Also enables individuals to make digital health appointments with payment online WHO health alert on WhatsApp, proactive communication tool providing the public with information on measures to prevent spread and exposure to COVID-19	Zipline (USA Company) with contracts with government institutions or departments in Ghana and Rwanda Government of Rwanda in partnership with the United Nations Development Programme (UNDP) Implemented in 16 African countries, including Kenya, South Africa, Ghana, and Rwanda Ethiopia, Uganda, and South Africa are examples of countries implementing the innovation

Source: EIB. (2020).

As stated earlier, Mugabe, et al. (2020) also provide examples of various scientific initiatives and technological innovations with the potential to tackle COVID-19 health challenges. It describes initiatives for COVID-19 clinical trials and vaccine development, such as the 'repurposing' of the South Africa AIDS Vaccine Initiative (SAAVI) accumulated scientific capabilities and infrastructure to engage in the rapid development of COVID-19 vaccines. The study also profiles efforts or programmes for harnessing the phytochemical potential of biodiversity and indigenous knowledge to develop health products to tackle COVID-19 in Africa.

Other examples of promising health innovations for COVID-19 include the diagnostic kit developed and released by the Kenya Medical Research Institute (KEMRI). Building on accumulated scientific and technological capabilities for diagnostics research for HIV and tuberculosis (TB), KEMRI recently innovated and released kits for rapid testing of COVID-19; Cobas 6800 viral load testing equipment. The South African National Bioinformatics Institute (SANBI) recently completed sequencing the whole genome of SARS-CoV-2 isolated from a patient with COVID-19. This somewhat innovatively helped provide the data necessary to determine the COVID-19 variants in South Africa. In addition to these R&I efforts, some African countries (e.g. South Africa and Kenya) are participating in the international clinical trials by Johnson and Johnson for COVID-19. South Africa is involved in several COVID-19 vaccine trials. For example, the University of the Witwatersrand has been involved in two COVID-19 vaccine trials; the Novavax product called NVX-CoV2373 and the Oxford COVID-19 vaccine trial, which uses the ChAdOx1 COVID-19 vaccine.

The World Health Organization (WHO) Regional Office for Africa issued a statement on 29 October 2020 providing an analysis of the health technology innovations that have been stimulated by COVID-19 in Africa. The analysis concludes that Africa accounts for 12.8% of the 1000 or so new or modifications of existing technologies that have been developed worldwide to target different areas of the COVID-19 response" (WHO, 2020). It shows that digital innovations or ICT-driven innovations take a large share of the African health innovations, accounting for about 58% of the total innovation. 3D printing related innovations account for 25%, and robotics make up 10.9% of the innovations deployed to address health challenges related to the pandemic in Africa. Most of these innovations are introduced or deployed in South Africa (13%), Kenya (10%), Nigeria (8%), and Rwanda (6%) (WHO, 2020).

The next section of the paper focuses on systemic barriers to the dominant promising health innovations for COVID-19 in Africa. While three clusters of innovations were highly rated to be critical and penetrating in African health systems (WHO, 2020), the barriers identified by respondents and FGD participants are described, and their systemic nature is analysed below.

6. Systemic barriers to health innovations

Much of the existing Africa-specific literature does not explicitly deal with barriers to health innovations. However, there is innovation literature that deals with barriers in general. Table 4 below shows the barriers to innovation highlighted in existing literature as well as the findings on barriers to health innovations from the study participants. Since the findings on barriers to health innovations are the focus of this paper, they are further explained.

Table 4: Barriers to health innovations.

Barriers to innovation and systematic barriers to health innovations highlighted in existing literature	**Systematic barriers to health innovations from respondents**
Economic cost of the innovation	Access to information
Cost of the innovation	Digital literacy
Lack of financing	Weak or poor infrastructure
Organisational rigidities	Policy and regulatory barriers
Skills shortages	High cost of procurement
Information asymmetries about the technology	Social resistance
Lack of market information	
Unresponsive customers	
Government regulations	

Source: Authors' own.

There are six main (highly rated by interviewees and participants in the FGD) systemic or interacting barriers to health innovations for tackling COVID-19 in Africa. These barriers are: (a) limited access to information on the innovations; (b) low levels of digital literacy; (c) weak infrastructure, particularly limited and unreliable supply of electricity; (d) weak policy and regulatory regimes; (e) high economic costs of procuring and deploying the innovations in low-income or poor households/communities; and (f) social resistance to innovations, particularly anticipated resistance to COVID-19 vaccines and therapeutics.

From the reviewed literature, we noted that other barriers to health innovations are weak links between research institutions and industry and low levels of funding of scientific research on COVID-19 in many African countries. Some of the potential COVID-19 testing kits developed by African institutions such as KEMRI in Kenya are likely to be stunted innovations because there are no explicit strategies to commercialise them, and institutional arrangements for getting private companies to invest in mass production are weak. Related to this is low funding for R&D that is likely to create discontinuity in scientific research, such as the SAR-s genome sequencing efforts that are pathways to vaccine development in Africa.

We elaborate on each of the six main barriers below.

6.1. Access to information

Limited (or lack of) access to information on the various health innovations and their applications is one of the major barriers to their diffusion and deployment to tackle the COVID-19 pandemic. Most of the study participants noted that people and health workers in rural areas of Africa do not have information on the existence of the different digital innovations for COVID-19. Some interviewees and respondents held the view that even in urban areas, there is limited information on the various digital innovations. This viewpoint is also expressed in existing literature, such as in the EIB and AUDA-NEPAD reports. Because many individuals and households do not have information (on the existence and applications), digital health innovations are likely to be under-utilised in the fight against the pandemic.

The information problem is associated with poor or weak marketing by private innovators and weak support by governments to publicise innovations from private individuals and companies. According to one interviewee, “governments are not actively prospecting for and promoting technologies or inventions that can be used to manage COVID-19 and other diseases in Africa. They wait for newspapers and other forms of media to market new innovations.”

6.2. Digital literacy

The spread and utilisation of digital health innovations, both in healthcare systems and households, are limited by low levels of digital literacy. The use of self-assessment applications such as Wellvis (a health care application that individuals can use to diagnose

themselves and contact medical emergency workers) is largely undermined or constrained by illiteracy among households, particularly in low-income rural areas. According to EIB (2020) and several interviewees, many of the self-assessment or self-diagnosis tools for COVID-19 are not easily accessible to illiterate people, particularly elderly ones in rural areas.

6.3. Weak or poor infrastructure

In countries or regions and households with low or poor electricity access and mobile phone penetration as well as internet connectivity, digital health innovations are unlikely to diffuse rapidly and be effectively deployed to address health aspects of the COVID-19 pandemic. These countries and communities will have difficulties managing COVID-19 vaccines when they are finally available in the market. According to the EIB (2020) report, "a lack of electricity and internet are major challenges identified in the interviews, in remote areas and in cities. (…) The second significant issue is the lack of internet servers, data centers and electricity supporting the digital technology in place or in development" (p. 20). Study participants in FGDs identified poor or limited access to electricity as a major barrier to the use of digital innovation in health systems and households in many African countries.

6.4. Policy and regulatory barriers

The absence of coherent, holistic policy measures and weak implementation of existing STI policies, as well as weak regulatory frameworks for health innovation, stand in the way of harnessing new medical technologies to fight the COVID-19 pandemic in Africa. African Academy of Science (2020) and Mugabe, et al. (2020) discuss how weak regulatory frameworks affect clinical trials and registration of medicines and medical products. According to Mugabe, et al. (2020), "regulatory mechanisms and frameworks for health R&D in general and clinical trials in particular are weak in most African countries. Costs – time and money – of clinical trials are relatively high in some countries. Institutional arrangements for regulating – including approval – health R&D and clinical trials in particular – are weak. Multiple agencies and ambiguous procedures make it cumbersome to get approvals for health R&D as well as clinical trials. This may undermine the continent's efforts to participate in global vaccine initiatives and related R&D. It acts as a disincentive for private industry to engage with public health R&D and clinical trials" (p. 22).

In South Africa, any application for a clinical trial for a vaccine has to go through the Medical Control Council approval, the ethics approval board, and registration with the Department of Health before it is given a unique number in the South African National Clinical Trial Register. The application then goes through monitoring and periodic review, and finally, it has to be submitted to SAHPRA, which through its Medicinal Evaluation and Research Unit, will determine whether to register the vaccine. This process takes a relatively long time, is cumbersome, and may be a barrier to COVID-19 vaccine approval and distribution in the country if it is followed to the letter.

6.5. High costs of procurement

Economic costs of some of the COVID-19 health innovations are relatively high for some countries and communities, particularly for poor or low-income households. Study participants identified high cost as a barrier to the spread and use of various health innovations, including approved quality masks and PPEs in general. Some countries are experiencing shortages of PPEs because of the relatively high costs of importing them and the lack of domestic capabilities to produce them locally. According to some interviewees, some producers of PPEs and high-quality masks complain of small fragment markets for durable medically approved PPEs.

6.6. Social resistance

Some of the health innovations, e.g. masks, social distancing practices, and potential vaccines, face social resistance-related barriers. Social resistance is often associated with misinformation or lack of information about the safety and utility of some health innovations (e.g. vaccines and diagnostics). According to some interviewees and all participants in the FGDs, COVID-19 innovations that face (or are likely to face) social resistance are social distancing, mask-wearing, and vaccines when they are available in Africa.

7. Measures to unlock systemic barriers to COVID-19 innovations

Overall, the main identified barriers to developing, diffusing, and deploying health innovations to tackle COVID-19 are not technological but relate to infrastructure (energy and connectivity), policy and regulations, social and economic, weak institutional articulation or linkages, literacy and information access. These barriers affect the dominant innovations, which are digital ones, in the fight against COVID-19. To remove or unlock these barriers will require a wide range of interventions beyond traditional STI policies and programmes. In this section, we suggest some of the most feasible measures to remove the barriers or impediments to health innovations.

The barriers to health innovations for COVID-19 are embedded in countries' national systems of innovation and interact in various systemic ways. For example, low levels of digital literacy are, in part, due to poor education and training and a lack of exposure to digital technologies as much as they are exacerbated by weak or poor internet connectivity. Weak internet connectivity is, to a large measure, related to weak infrastructure, including poor access to electricity. Barriers such as poor or limited access to electricity and internet connectivity tend to affect innovation processes and activities, thus impeding the generation or production (not just the spread and deployment) of new innovations.

Thus, because of their systemic nature, measures to address or remove the barriers need to be systemic in order to have an effect in the NSI in general and health innovation systems in particular. This approach, drawing on a recent study by Borras and Edquist (2019), is based on the view that a mix of holistic policy instruments and related institutional arrangements is needed to remove or unlock barriers to innovation. As stated before, in this paper, policy

instruments refer to measures or actions that governments purposefully institute in order to influence innovation processes and activities aimed at addressing health challenges associated with the COVID-19[2].

The range of policy instruments available to governments to unlock barriers to innovations for tackling health challenges of COVID-19 is relatively wide in the sense that it covers social, economic and fiscal, regulatory, manufacturing and industrial, R&D, education and training, and other facets of public policy. In this regard, the challenge for governments pertains to choosing instruments that can be implemented effectively and efficiently during the crisis and uncertain times of the pandemic. The choice of policy instruments should be informed by criteria such as state capability and flexibility for adjustment based on policy learning.

To address the information access deficits and social resistance barriers identified in this study, respondents noted that governments should consider invoking and using access to information provisions in national constitutions. Most national constitutions have such provisions requiring state agencies to ensure that citizens have access to information, particularly on the issue of public emergency and/or concern. To implement access to information provisions and help remove information barriers to health innovations for COVID-19, governments should design and launch public information and awareness programmes for approved COVID-19 digital innovations and treatments, including vaccines and medicines. Such programmes would focus on raising awareness of the availability, utility, and applications of various approved COVID-19 innovations. They would involve the use of media, including print, radio and television, to communicate messages or information on available innovations. Community innovation outreach and demonstration activities led by relevant government departments, private firms, and individuals involved in developing specific innovations would also help to disseminate information on and build public understanding of how to use such innovations to address COVID-19 health challenges.

Removing barriers associated with the high economic costs of procuring and deploying COVID-19 will require dedicated fiscal or financial instruments. Governments should consider establishing national COVID-19 innovation funds that would provide positive incentives to individuals, households, and even community-based agencies to procure approved health innovations, such as testing kits. The financial instruments – COVID-19 innovation funds – would comprise of cash grants, interest-free loans, cash transfers, and loan guarantees that innovators may also access in order to help scale and mass produce their products. For example, South Africa, among other few African countries, has been providing cash transfers to cushion selected groups of vulnerable persons from the effects of COVID-19.

A related measure pertains to industrial policies that will help repurpose private industrial activities, which will be necessary to leverage existing innovation capabilities to address production or manufacturing challenges. Financial instruments that enable Small and

[2] For a more elaborate and broad definition of policy instruments, see Borras & Edquist, (2019).

Medium Enterprises (SMEs) to access financial means to help produce PPEs and other products are needed to strengthen local and national health systems.

To address weak or poor infrastructure barriers, including electricity and internet connectivity, African governments and private sector actors in collaboration with international partners need to urgently explore possibilities to fast-tracking connectivity to various sources of energy (such as solar). Poor access to reliable electricity hinders the use of different digital innovations and keeps local health systems at the periphery of technological change. One approach to addressing this challenge is to establish national schemes that enable households and communities, particularly in rural areas, to procure solar and other off-grid sources of electricity cheaply and in more rapid ways. Community-based energy facilities that are developed and managed by local cooperative groups, including women's associations, should be encouraged through various fiscal incentives and technical capacity building programmes.

In order to strengthen existing policy and regulatory frameworks, governments of African countries need to urgently institute critical reviews or assessment and revision of existing national policies, legislation and regulations for clinical trials, and registration of health products to make them flexible enough to allow for rapid innovation, including using various public procurement mechanisms to promote domestic or endogenous manufacturing of pharmaceuticals. African countries need to invest in policy learning, drawing lessons from experiences of countries such as India and South Korea that have been able to improve efficiencies in clinical trials and procurement as well as local manufacturing of health products.

Overall, COVID-19 is a transformative pandemic requiring transformative responses. As such, the focus should be on exploiting technological convergences and innovations that produce systemic outcomes. A holistic approach based on NIS approaches is essential. Notably, the need for fewer silos between systems (health, industry, education) and the establishment of a more coherent well capacitated NIS is necessary. Single technologies or innovations will not fix the pandemic and its health consequences. Investments in carefully chosen mixes of innovation activities and processes are needed. As stated earlier, this will depend on mixes of policy instruments that support research and development (R&D), technology incubation, scaling up technology production or manufacturing, and quality of technical standards.

8. Conclusions

This paper shows that COVID-19 has stimulated a surge in various health innovations in Africa. Most of the innovations are digital, involving various applications for testing and tracing as well as monitoring and surveillance to control the spread of coronavirus. Some African countries have deployed modern technologies such as robotics in their health systems to help curb the spread of the virus and contain the disease. There are also scientific research initiatives and clinical trials in some countries offering the potential for vaccine development. However, these initiatives are undermined by various barriers, including

information access deficits, low levels of digital literacy, weak policy and regulation measures, and poor institutional arrangements. Fiscal and non-fiscal measures, including various mixes of policy instruments, are proposed to unlock the barriers in order to harness the potentials of the innovations to tackle health aspects of the COVID-19 pandemic.

For future research, the nexus between health and industrialisation or manufacturing is under-studied in Africa. There is scant empirical research on how industrial change (or industrial development) can aid (transform) public health, particularly in terms of reducing the costs of local manufacturing of medicines and medical equipment. Empirical data and evidence-based policy analysis are needed to help improve the integration of health considerations into national industrial policies and programmes and to stimulate industrial production for health and wellbeing. Such research would generate and provide evidence to policymakers and practitioners in health and industrial sectors to help fast track innovations that address epidemics and health emergencies such as COVID-19. It will seek to help unlock barriers to technological innovation in national health systems and promote ways and means of narrowing inequalities related to access to health innovations.

African countries are exposed to a wide range of technological and non-technological opportunities that would help to fight COVID-19. Tapping these opportunities will require deliberate and urgent policy and programmatic actions, including technology assessment and procurement given the high demand for technologies to fight COVID-19 in the face of growing techno-nationalism, i.e. a process whereby states have become inwardly looking and prioritising their citizens and persons resident in their countries and less concerned about non-citizens. Any efforts at promoting invention, technology development, and innovation to address the pandemic should be informed by specific needs or demands of African innovation systems in general and health innovation systems in particular. Like other continents, African innovation systems are diverse, evolving, and characterised by differentiated strengths and weaknesses. Different African countries have different absorptive technological capabilities. However, there are similarities in the nature of the barriers to health technologies and innovations for COVID-19. Measures for promoting COVID-19 health innovations should be cast in the broader context of unlocking the barriers and strengthening national innovation systems.

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